Bigger animals such as elephants use more energy, but they are also much more efficient users of energy. This allometric scaling of metabolism with mass may also occur with offspring size.

Eric Isselée/adobe

Why are bigger offspring better?

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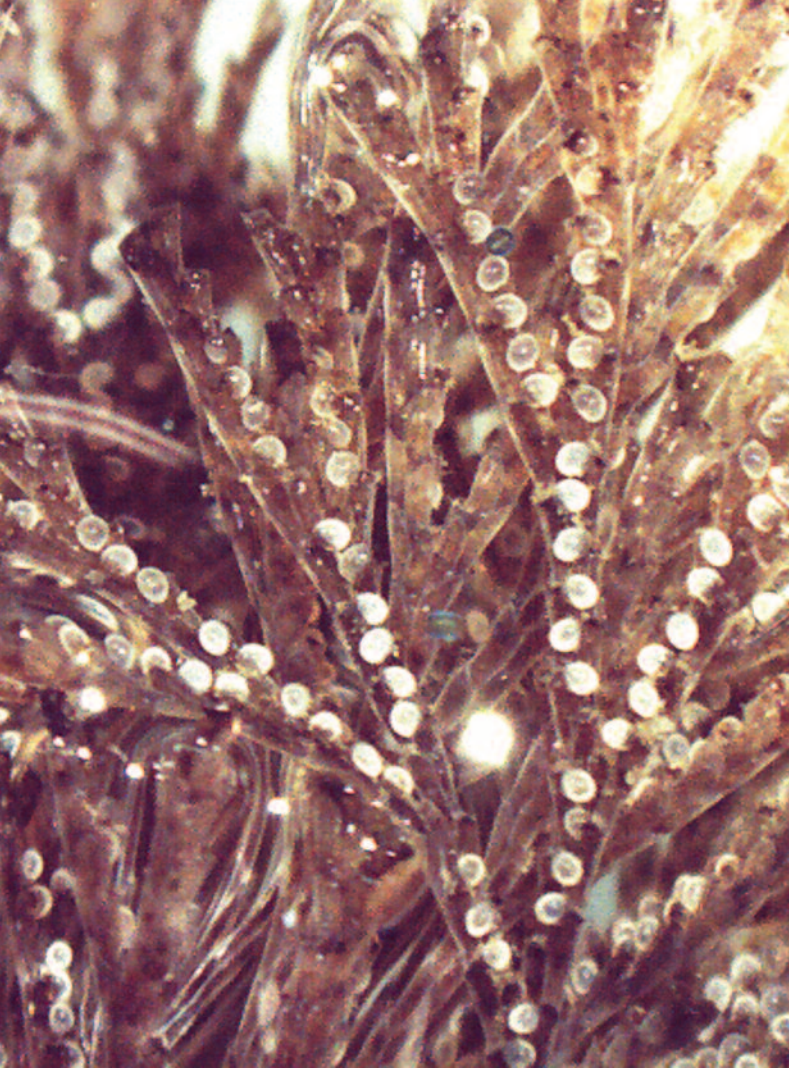
Bigger offspring have greater energy needs, so why do they survive and reproduce more successfully than their smaller siblings?

We've all heard of the phrase: "A big baby is a healthy baby", but this isn't just an old wives' tale. Larger offspring do perform better than smaller offspring, and this pattern has been observed by ecologists for decades. Across the many organisms that have been studied, including reptiles, birds, fish, insects and even in plants, we see that larger offspring are often "fitter" than smaller offspring. Larger offspring generally survive better, grow bigger, reproduce more and are less vulnerable to starvation and predation.

The effects of offspring size can pose consequences for later life. Not only do bigger offspring grow into fitter juveniles and adults; offspring size differences can affect later generations.

We wanted to know why this was the case. When it comes to offspring size, why is bigger, better?

Many studies have attempted to explain why this pattern occurs, and have tested some interesting theories. Some propose that larger offspring have more energy, which is a reasonable assumption. However, we must also consider that the energy required to maintain a larger size are also higher. Larger offspring



These *Bugula* colonies look like seaweed, but they are actually animals comprised of thousands of subunits that release swimming larvae into the ocean.

may also be able to feed more successfully and therefore gain more energy than smaller offspring, or they might reach a size that gives them access to a refuge from predation.

Despite these intriguing insights into the advantages of larger offspring size, they often depend on the species being studied. We still don't know why these patterns are so widespread.

What could serve as a more general explanation as to why bigger offspring do better? We decided to view offspring size from a perspective that is relevant to all living organisms: metabolic scaling.

Metabolic scaling is central to metabolic theory, and is a key element of physiological research. Metabolic scaling describes the relationship between body size and energy use: for every increase in body size there is a less than proportional increase in energy use. If we plot the relationship between mass and metabolic rate on a log–log scale, then for every one unit increase in mass the increase in metabolic rate is a less than one unit. So, as body size increases, relative energy use decreases (see box, p.33).

This theory is pretty much universal – per unit of mass, larger individuals burn less energy than smaller individuals. So if this relationship exists for elephants and mice, then what about their offspring? We tested whether bigger offspring consume relatively less energy than smaller offspring in two species of marine bryozoan, *Bugula neritina* and *Watersipora subtorquata*.

While they may look like seaweed or some strange coral, bryozoans (commonly known as "moss animals") are one of the most abundant phyla of marine invertebrates to inhabit our oceans. You can find bryozoan colonies occupying space on piers and pylons. Each colony is considered an individual comprised of subunits.

The colonies reproduce both asexually (by "budding" identical subunits) and sexually (by producing sperm and eggs). Adult-stage colonies can brood thousands of fertilised eggs at a time. These develop and are released as tiny swimming larvae into the water, where they search for suitable settlement sites. During this time, the larvae of both species do not feed; they only develop feeding structures once they have settled and undergone a dramatic transformation of their body structure. This metamorphosis can take 3–5 days, during which individuals are dependent on energy stored during gestation, much like the energy provided by a human mother to her baby via the placenta.

This is a critical period in the life cycle of bryozoans, and high mortality rates occur. Maternal provisions give the offspring a better chance of survival. Previous research in our laboratory has shown that by making bigger larvae a mother can improve the odds of survival for her offspring. We found that bigger babies are able to survive this dependent phase much longer than smaller larvae.

To test metabolic scaling on bryozoans, we spawned colonies of *Bugula* and *Watersipora* in the lab and measured the size of individual larvae. Within a single colony a mother can produce a range of larval sizes, with some larger larvae up to three times the size of their smaller siblings.

We placed individual larvae into tiny metabolic chambers measuring just 0.2 mL in volume, and measured the rate of oxygen consumption as a proxy for metabolic rate. The slope of the relationship between offspring size and metabolic rate was then tested.

We found an allometric relationship between offspring size and metabolic rate – the slope of the relationship was less than one. Per unit of body mass, larger offspring used much less energy as they developed through the critical dependent phase (from swimming larvae through to feeding settler) than smaller offspring. This finding was found for both species of bryozoan.

Thus we showed that, proportional to their size, larger offspring reached independence with a higher amount of the initial energy supplied to them by their mother. As a result, these larger offspring developed into juveniles with more energy reserves, and therefore had a head start in life over smaller offspring. They could use this extra energy to feed and grow more, and ultimately survive to reproduce.

Using metabolic theory, we were able to provide a general explanation for a common pattern observed in ecological studies. Our research highlights the importance of measuring metabolism, not only in adult stages but in the offspring, to explain why experiences early in the life cycle can pose important consequences for fitness later on in life.

Offspring size matters, and energy use during this critical life stage can determine how each individual fares throughout its development.

These findings offer exciting new avenues of research into the energetics of offspring, from both a physiological, evolutionary and ecological perspective. It will be interesting to see whether allometric scaling occurs in the offspring of other species and whether it does indeed offer a universal explanation for why a big baby is a healthy baby.

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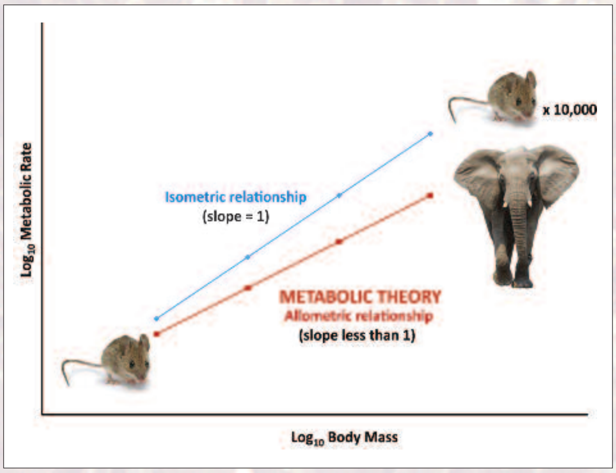
Metabolic Scaling: Why Size Matters

Metabolic theory research studies the flux of energy in ecology. A central tenet of metabolic theory is that as body size increases, metabolic rate also increases but to a lower extent. Metabolic rate does not increase proportionally with mass; rather, the relationship is often allometric: for every unit gain in mass, there is a smaller increase in metabolic rate.

For example, an elephant has a mass approximately 10,000 greater than a single mouse. The elephant clearly uses far more energy and has a higher metabolic rate overall. However, if we then measure the total energy metabolism of 10,000 mice, the combined energy metabolism of the mice would be far greater than that of a single elephant of equivalent mass.



This is called allometric scaling, where for every increase in mass there is a smaller incremental increase in metabolic rate. If we plot this relationship on a log–log scale we see a linear relationship between mass and metabolic rate, but the rate of increase in metabolic rate is almost always less than one. This relationship is found both among and within species, and has been tested by physiologists for over 100 years.

The reasons behind this allometric scaling between metabolic rate and body size have been hotly debated, and include explanations involving physics and biochemistry such as the relationship between metabolic rate and body surface area, heat exchange and the distribution of resources.